DEQ

WATER BUREAU
POLICY AND PROCEDURES

NUMBER:	**WB - 015**	
SUBJECT:	**SIGNIFICANT FIGURES**	
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REVISION DATE:	(5-YEAR REVIEW FREQUENCY)	

ISSUE:

The minimum number of digits required to report a value without loss of accuracy is the number of significant figures. In scientific work, most numbers are measured quantities and are not exact. All measured quantities are limited in significant figures by the precision of the instrument used to make the measurement. It is important to use significant figures when recording a measurement or calculation so that it does not appear to be more accurate than it really is.

There are various approaches for determining significant figures and rounding of numbers. This general guidance is intended to clarify the number of significant figures to be used to report self-monitoring results on Discharge Monitoring Reports (DMRs), state permit limits, determine compliance, or other Water Bureau programs as appropriate.

AUTHORITY:

The Natural Resources and Environmental Protection Act, 1994 PA451, as amended, the federal Clean Water Act, and associated administrative rules.

DEFINITIONS:

DMR Discharge Monitoring Report

POLICY:

It is the Water Bureau policy to follow generally accepted procedures for determining significant figures and rounding numbers to support monitoring, compliance and enforcement activities. It is intended to be consistent with Section 1050 B of *Standard Methods for the Examination of Water and Wastewater* (18th, 19th and 20th editions). Section 1050 B of the 19th edition is attached for further discussion and examples.

REFERENCE TO BUREAU PROGRAMS: All Water Bureau programs as appropriate.

METHOD OF DISTRIBUTION: - Intranet and electronic mail distribution.

PROCEDURE: The procedure below is organized into the following topics:

General Rules
Rules for Significant Figures
Rules for Rounding
Rules for Precision

I. General Rules

- Significant figures should be determined consistent with guidance specified in recent editions of *Standard Methods for the Examination of Water and Wastewater.*

- Permit limits are generally expressed using no more than two significant digits and reporting should be consistent with the same number of significant digits as the permit limits.

- When the permit limit is expressed as a single significant figure, analytical results shall be reported as one significant figure when the result is of the same magnitude, but should be reported as two significant figures when the result is a higher magnitude and the analysis supports that level of accuracy. For example, a result of 4.3 for a permit limit of 5 should be reported as 4. If the result is 12, it should be reported as 12 (two significant figures) if supported by analytical procedures.

- If the permit does not specify the number of significant digits, measurements shall be reported in two significant digits except in the cases of total suspended solids and biochemical oxygen demand (BOD) where single digit effluents are achieved.

- BOD monitoring results should be reported as a whole number because the method is not accurate enough to provide data beyond a whole number.

- All calculations (i.e. averaging and multiplying) should be completed before any rounding takes place.

It is important to follow accepted mathematical conventions for DMR reporting. The following rules apply for measured values such as concentration. They are not intended for conversion factors.

II. Rules for Significant Figures

Regardless of the measuring device, there is always some uncertainty in a measurement. Significant figures include all the digits in a measurement that are known with certainty as well as the last digit, which is an approximation.

- All non-zero digits (1-9) are to be counted as significant.

- All zeros between non-zero digits are always significant. Both 3906 and 20.04 contain four significant digits.

- For numbers that do not contain decimal points, the trailing zeros may or may not be significant. The number 630,000 may have two to six significant digits. Scientific notation can be used to avoid the uncertainty of ambiguous zeroes. Footnotes or boilerplate language can also be used to specify the number of significant figures.

- For numbers that do contain decimal points, the trailing zeros are significant. Both 0.420 and 3.00 have three significant digits.

- If a number is less than 1, zeros that follow the decimal point and are before a non-zero digit are not significant. Both 0.00352 and .0780 contain three significant digits.

III. Rules for Rounding

Examine the digit following the last digit to be reported. This digit is the one that is referred to as "being dropped" when rounding.

- If the digit being dropped is 0, 1, 2, 3, or 4, leave the preceding number as it is.

  Example: 31.2846 rounded to two significant figures, becomes 31.

- If the digit being dropped is 6, 7, 8, or 9, increase the preceding digit by one.

  Example: 6.378 rounded to two significant figures becomes 6.4.

- If the digit 5 is being dropped, round off the preceding digit to the nearest even number (zero is considered an even number when rounding off).

  Example: 4.25 becomes 4.2; 4.35 becomes 4.4.

IV. Rules for precision

Monitoring results should be reported with the same degree of precision that was achieved in the analysis/measurement of the value. This means that numbers resulting from calculations, including loadings, cannot be more precise than the raw data used in the calculations.

- For addition or subtraction, the answer can contain no more decimal places than the least number of decimal places in any of the numbers being added or subtracted.

- For multiplication or division, the least number of significant figures in any of the measurements determines the number of significant figures in the answer.

- Numbers such as conversion factors or number of days are counted numbers and are not considered when determining the number of significant figures or decimal places in the calculation.

- If both addition/subtraction and multiplication/division are used in the calculation, follow the rules for multiplication/division.

- When doing multistep calculations, keep at least one more significant digit in intermediate results than needed in your final answer. This eliminates the problem known as "round-off error."

Example: Calculate total suspended solids mass limit

Q x C x Unit Conversion = Mass Loading

0.53 mgd x 8 mg/l x 8.34 = 35.3616 lb/d

Precision rule in bullet #2 applies.
The number 3 in the result is the significant figure.
The digit five in the ones place is dropped. (Rules for Rounding bullet #3)

Enter 40 lb/d as the calculated result.

Example: Calculate the 7-day average for BOD

C = 23, 16, 12, 18, 25 (mg/l). Sampled 5 times

$$\frac{23 + 16 + 12 + 18 + 25}{5} = 18.8$$

Precision rules in bullets #3 and #4 apply. (The 5 in the denominator is a counted value)
The numbers 1 and 8 are the two significant figures.
The number 8 in the tenths place is rounded up. (Rules for Rounding bullet #2)

Enter 19 mg/l as the calculated result.

Responsibility:

Each Water Bureau program area shall evaluate this procedure to see how it applies to its program. For example, Permits Section shall evaluate how to express treatment technology and water quality based effluent limits in permits.

APPROVED: _____ DATE: 2/8/08

Richard A. Powers, Chief
Water Bureau

LAST REVIEWED BY: _____ DATE: _____

Name
Title

This policy provides guidance to staff regarding the implementation and interpretation of laws administered by the DEQ. It is merely explanatory, does not affect the rights of or procedures and practices available to the public, and it does not have the force and effect of law.

1050 B. Significant Figures

1. Reporting Requirements

To avoid ambiguity in reporting results or in presenting directions for a procedure, it is the custom to use "significant figures." All digits in a reported result are expected to be known definitely, except for the last digit, which may be in doubt. Such a number is said to contain only significant figures. If more than a single doubtful digit is carried, the extra digit or digits are not significant. If an analytical result is reported as "75.6 mg/L," the analyst should be quite certain of the "75," but may be uncertain as to whether the ".6" should be .5 or .7, or even .4 or .8, because of unavoidable uncertainty in the analytical procedure. If the standard deviation were known from previous work to be ±2 mg/L, the analyst would have, or should have, rounded off the result to "76 mg/L" before reporting it. On the other hand, if the method were so good that a result of "75.61 mg/L" could have been conscientiously reported, then the analyst should not have rounded it off to 75.6.

Report only such figures as are justified by the accuracy of the work. Do not follow the all-too-common practice of requiring that quantities listed in a column have the same number of figures to the right of the decimal point.

2. Rounding Off

Round off by dropping digits that are not significant. If the digit 6, 7, 8, or 9 is dropped, increase preceding digit by one unit; if the digit 0, 1, 2, 3, or 4 is dropped, do not alter preceding digit. If the digit 5 is dropped, round off preceding digit to the nearest even number: thus 2.25 becomes 2.2 and 2.35 becomes 2.4.

3. Ambiguous Zeros

The digit 0 may record a measured value of zero or it may serve merely as a spacer to locate the decimal point. If the result of a sulfate determination is reported as 420 mg/L, the report recipient may be in doubt whether the zero is significant or not, because the zero cannot be deleted. If an analyst calculates a total residue of 1146 mg/L, but realizes that the 4 is somewhat doubtful and that therefore the 6 has no significance, the answer should be rounded off to 1150 mg/L and so reported but here, too, the report recipient will not know whether the zero is significant. Although the number could be expressed as a power of 10 (e.g., 11.5×10^2 or 1.15×10^3), this form is not used generally because it would not be consistent with the normal expression of results and might be confusing. In most other cases, there will be no doubt as to the sense in which the digit 0 is used. It is obvious that the zeros are significant in such numbers as 104 and 40.08. In a number written as 5.000, it is understood that all the zeros are significant, or else the number could have been rounded off to 5.00, 5.0, or 5, whichever was appropriate. Whenever the zero is ambiguous, it is advisable to accompany the result with an estimate of its uncertainty.

Sometimes, significant zeros are dropped without good cause. If a buret is read as "23.60 mL," it should be so recorded, and not as "23.6 mL." The first number indicates that the analyst took the trouble to estimate the second decimal place; "23.6 mL" would indicate a rather careless reading of the buret.

4. Standard Deviation

If, for example, a calculation yields a result of 1449 mg/L or 1451 mg/L with a standard deviation of ±100 mg/L, report as 1449 ± 100 mg/L or 1451 ± 100 mg/L, respectively. Ensure that the number of significant figures in the standard deviation is not reduced if the value is 100 ± 1. This could cause incorrect rounding of data to 1400 or 1500 mg/L, respectively.

5. Calculations

As a practical operating rule, round off the result of a calculation in which several numbers are multiplied or divided to as few significant figures as are present in the factor with the fewest significant figures. Suppose that the following calculations must be made to obtain the result of an analysis:

$$\frac{56 \times 0.003\,462 \times 43.22}{1.684}$$

A ten-place calculator yields an answer of "4.975 740 998." Round off this number to "5.0" because one of the measurements that entered into the calculation, 56, has only two significant figures. It was unnecessary to measure the other three factors to four significant figures because the "56" is the "weakest link in the chain" and limits accuracy of the answer. If the other factors were measured to only three, instead of four, significant figures, the answer would not suffer and the labor might be less.

When numbers are added or subtracted, the number that has the fewest decimal places, not necessarily the fewest significant figures, puts the limit on the number of places that justifiably may be carried in the sum or difference. Thus the sum

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  0.0072
 12.02
  4.0078
 25.9
4886
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4927.9350
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must be rounded off to "4928," no decimals, because one of the addends, 4886, has no decimal places. Notice that another addend, 25.9, has only three significant figures and yet it does not set a limit to the number of significant figures in the answer.

The preceding discussion is necessarily oversimplified. The reader is referred to mathematical texts for more detailed discussion.

ATTACHMENT